CONTRACTS NAS1-12954 AND NAS1-14724

FLIGHT-SERVICE PROGRAM FOR ADVANCED COMPOSITE RUDDERS ON TRANSPORT AIRCRAFT

July 1979

Third Annual Summary Report
Covering airline service between
1 June 1978 and 30 June 1979

McDonnell Douglas Corporation

Douglas Aircraft Company
3855 Lakewood Blvd.
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Prepared for Langley Research Center

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FOREWORD

This report was prepared by the Douglas Aircraft Company, McDonnell Douglas Corporation, Long Beach, California, under Contracts NAS1-12954 and NAS1-14724. It is the third annual summary report covering airline service experience between 1 July 1978 and 30 June 1979. The program is sponsored by the National Aeronautics and Space Administration (NASA), Langley Research Center. Mr. Marvin B. Dow is the Technical Representative of the Contracting Officer for NASA.

The following Douglas personnel were the principal contributors to the program during the reporting period: G. M. Lehman, Technical Director for Contract NAS1-12954; A. Cominsky, Project Manager for Contract NAS1-14724; V. O. Brinkmann, Customer Service and Product Support; V. J. Cusimano, Non-Destructive Inspection; and C. Y. Kam and R. L. Hope, Moisture Absorption Investigation.

This report was prepared under Douglas Report No. MDC J6574, Volume XI. It was released by the authors for publication in August 1979.

SUMMARY

Flight service experience and in-service inspection results are reported for DC-10 graphite composite rudders during the third year of airline service. Test results and status are also reported for ground-based and airborne graphite-epoxy specimens with three different epoxy resin systems to obtain moisture absorption data.

Twenty graphite composite rudders have been produced, nine of which have been installed on commercial aircraft during the past three years. The rudders have collectively accumulated 75,863 flight hours. The high time rudder has accumulated 12,740 flight hours in slightly over 36 months. The graphite composite rudders have been inspected visually at approximately 1000 flight hour intervals and ultrasonically at approximately 3000 flight hour intervals in accordance with in-service inspection plans. All rudders have been judged acceptable for continued service as a result of these inspections.

Status of a program to obtain composite moisture absorption data on small specimens, both ground-based and carried aboard three flight-service aircraft, is reported. The specimens include Thornel 300 fibers in Narmco 5208 and 5209 resin systems, and Type AS fibers in the Hercules 3501-6 resin system. Results are presented for service exposures up to about one year duration.

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SECTION I
INTRODUCTION

Twenty advanced composite rudders for the DC-10 Commercial transport aircraft have been produced by the Douglas Aircraft Company, 10 each under Contracts NAS1-12954 and NAS1-14724. Overall objectives of these contracts were (1) development of technology to design and fabricate composite structural components for transport aircraft, (2) acquisition of manufacturing cost data, (3) development of confidence and experience in the use of composite materials in commercial aircraft, (4) acquisition of maintenance experience and cost data during airline flight-service, (5) acquisition of data for correlating flight-service behavior with ground based tests, and (6) broadening the base of experience and confidence in composite usage. An additional objective of the latter contract was to reduce manufacturing costs through development of production tools and methods.

In contract NAS1-12954, design and development of the composite rudders were completed using the Thornel 300/Narmco 5208 graphite-epoxy material system in unidirectional 3 inch tape form. The design, development, and testing of these rudders were completed and reported in November 1976 in NASA CR-145068, "Advanced Composite Rudders for DC-10 Aircraft - Design, Manufacturing, and Ground Tests." FAA certification was received in May 1976 and commercial flight service was initiated in June 1976.

In Contract NAS1-14724, design and development of the composite rudders were completed using the Thornel 300/Narmco 5208 graphite-epoxy material system in uni-woven and bi-woven cloth forms. The design, development, and testing of these rudders was completed on 15 October 1978 and will be reported in NASA CR-159060, "Manufacturing Development of DC-10 Advanced Rudder," presently in preparation. FAA certification was received on 3 May 1979 and the first rudder installation was accomplished at Douglas in July 1979. The aircraft is scheduled to start commercial service in February 1980.

Eight composite rudders from Contract NAS1-12954 were installed on operational aircraft at the time of the second annual flight service report (Reference 1) in July 1978. One additional rudder was installed during the past year. This report is the third annual summary report covering airline service experience of the nine composite rudder units during the third year of flight-service.

SECTION 2
RUDDER FLIGHT-SERVICE

In Contract NAS1-12954, flight-service agreements were consummated with five commercial operators for the flight-service phase. The participating operators are Korean, Western, Air New Zealand (ANZ), Trans-International (TIA), and Swissair Airlines. Ten composite rudders were manufactured and nine of these have been introduced into commercial airline service. Rudders are installed on three ANZ aircraft; three TIA aircraft; and one each on Western, Swissair, and Korean Airlines aircraft. The first installation was completed on the Korean Airline aircraft (then Air Siam) on 16 June 1976. In Contract NAS1-14724, ten additional rudders were produced, six of which will be installed on Swissair aircraft and four of which will be installed on ANZ aircraft.

The different thermal expansion characteristics between the graphite composite aft rudder and the aluminum alloy forward rudder necessitated a modification to the forward rudder hinge brackets. This modification was initially applied to a spare rudder assembly at Douglas. Subsequent units have been completed on a rotational basis by modifying the forward rudder removed from one aircraft for use during the next installation. Nine rudder units have now been installed on operational aircraft, eight during the first two years of flight-service and one during the third. The tenth forward rudder modification has been completed and installation on an ANZ aircraft is impending.

The flight-service rudders have collectively accumulated 75,863 hours of flight-service through June 1979. The high-time rudder has accumulated 12,740 hours in slightly over 36 months of service. Rudder flight service status through June 1979 is summarized in Tables 1 through 3. The overall rudder service experience to date has been excellent with no unusual maintenance activities required.

TABLE 1

FLIGHT-TIME ACCUMULATIONS FOR DC-10 GRAPHITE COMPOSITE RUDDERS – FIRST YEAR

		FLIGHT TIME ACCUMULATIONS (HOURS)																									
		1976														1977											
		JUN		JUL		AUG		SEP		OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		JUN	
OPERATOR AND FUSELAGE NO.	INSTALLATION DATE	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM
AIR SIAM/KOREAN NO. 125	6/16/76	152	152	324	476	328	804	323	1127	345	1472	74	1546	0	1546	0	1546	0	1546	226	1772	312	2084	370	2454	380	2834
WESTERN NO. 222	6/23/76	97	97	352	449	370	819	346	1165	336	1501	344	1845	370	2215	375	2590	329	2919	388	3307	352	3659	370	4029	345	4374
AIR NEW ZEALAND NO. 69	9/1/76	0	30*	0	30	0	30	260	290	400	690	377	1067	1409	1476	405	1881	353	2234	356	2590	401	2991	265	3256	425	3681
TRANS-INTERNATIONAL NO. 96	1/18/77															52	52	221	273	230	503	300	803	286	1089	365	1454
TRANS-INTERNATIONAL NO. 103	1/28/77																	199	199	215	414	270	684	346	1030	341	1371
TRANS-INTERNATIONAL NO. 110	2/10/77																	79	79	228	307	287	594	282	876	394	1270
TOTALS		249	279	676	955	698	1653	929	2582	1056	3663	795	4458	779	5237	832	6069	1181	7250	1643	8893	1922	10,815	1919	12,734	2250	14,984

*30 HOURS ACCUMULATED DURING DOUGLAS FLIGHT-TESTS

TABLE 2.

FLIGHT-TIME ACCUMULATIONS FOR DC-10 GRAPHITE COMPOSITE RUDDERS – SECOND YEAR

OPERATOR AND FUSELAGE NO.	INSTALLATION DATE	FLIGHT-TIME ACCUMULATIONS (HOURS)																							
		1977												1978											
		JUL		AUG		SEP		OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		JUN	
		MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM
KOREAN NO. 125	6/16/76	424	3,258	411	3,669	342	4,011	393	4,404	366	4,770	379	5,149	199	5,348	265	5,613	352	5,965	339	6,304	329	6,633	371	7004
WESTERN NO. 222	6/23/76	371	4,745	369	5,114	366	5,480	380	5,860	362	6,222	363	6,585	369	6,954	338	7,292	370	7,662	356	8,018	329	8,347	311	8658
AIR NEW ZEALAND NO. 69	9/01/76	195	3,876	421	4,297	356	4,653	[illegible]6	5,099	428	5,527	354	5,881	349	6,230	348	6,578	339	6,917	366	7,283	313	7,596	347	7943
TRANS-INTERNATIONAL NO. 96	1/18/77	375	1,829	376	2,205	115	2,320	0	2,320	0	2,320	105	2,425	185	2,610	252	2,862	290	3,152	211	3,363	244	3,607	270	3877
TRANS-INTERNATIONAL NO. 103	1/28/77	357	1,728	377	2,105	224	2,329	155	2,484	237	2,721	240	2,961	189	3,150	252	3,402	313	3,715	308	4,023	284	4,307	299	4606
TRANS-INTERNATIONAL NO. 110	2/10/77	386	1,656	395	2,051	82	2,133	0	2,133	0	2,133	127	2,260	280	2,540	279	2,819	303	3,122	288	3,410	271	3,681	333	4014
AIR NEW ZEALAND NO. 116	7/13/77	221	221	357	578	407	985	406	1,391	355	1,746	324	2,070	374	2,444	299	2,743	337	3,080	348	3,428	332	3,760	341	4101
SWISSAIR NO. 241	7/21/77							55	55	340	395	367	762	391	1,153	329	1,482	385	1,867	371	2,238	377	2,615	377	2992
TOTALS		2329	17,313	2706	20,019	1892	21,911	1835	23,746	2068	25,814	2259	28,093	2336	30,429	2362	32,791	2689	35,480	2587	38,067	2479	40,546	2649	43,195

TABLE 3

FLIGHT-TIME ACCUMULATIONS FOR DC-10 GRAPHITE COMPOSITE RUDDERS — THIRD YEAR

OPERATOR AND FUSELAGE NO.	INSTALLATION DATE	FLIGHT-TIME ACCUMULATIONS (HOURS)																							
		1978												1979											
		JUL		AUG		SEP		OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		JUN	
		MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM
KOREAN NO. 125	6/16/76	299	7,303	330	7,633	292	7,925	272	8,197	322	8,519	357	8,876	335	9,211	340	9,551	344	9,895	369	10,264	286	10,550	79	10,629
WESTERN NO. 222	6/23/76	398	9,056	389	9,445	359	9,804	372	10,176	372	10,543	368	10,911	383	11,294	300	11,594	358	11,952	370	12,322	361	12,683	57	12,740
AIR NEW ZEALAND NO. 69	9/01/76	396	8,339	370	8,709	364	9,073	387	9,460	301	9,761	378	10,139	383	10,522	377	10,899	262	11,161	419	11,580	359	11,939	90	12,029
TRANS-INTERNATIONAL NO. 96	1/18/77	391	4,268	308	4,576	375	4,951	346	5,297	262	5,559	171	5,730	272	6,002	290	6,292	143	6,435	270	6,705	293	6,998	79	7,077
TRANS-INTERNATIONAL NO. 103	1/28/77	363	4,969	364	5,333	303	5,636	377	6,013	325	6,338	251	6,589	297	6,886	284	7,170	321	7,491	338	7,829	239	8,068	60	8,128
TRANS-INTERNATIONAL NO. 110	2/10/77	398	4,412	395	4,807	308	5,115	288	5,403	321	5,724	225	5,949	276	6,225	289	6,514	329	6,843	260	7,103	295	7,398	65	7,463
AIR NEW ZEALAND NO. 116	7/13/77	360	4,461	366	4,827	350	5,177	335	5,512	307	5,819	462	6,281	415	6,696	334	7,030	384	7,414	382	7,796	386	8,182	158	8,340
SWISSAIR NO 241	7/21/77	343	3,335	400	3,735	345	4,080	375	4,455	370	4,825	419	5,244	401	5,645	355	6,000	328	6,328	380	6,708	376	7,004	125	7,209
AIR NEW ZEALAND NO. 213	11/22/78	–	–	–	–	–	–	–	–	68	68	371	439	375	814	260	1,074	382	1,456	378	1,834	337	2,171	77	2,248
TOTAL		2948	46,143	2922	49,605	2696	51,761	2752	54,513	2648	57,161	2997	60,158	3137	63,295	2829	66,124	2851	68,975	3166	72,141	2932	75,073	790	75,863

Selected composite rudders have been inspected visually at approximately 1000 flight-hour intervals and ultrasonically at approximately 3000 flight-hour intervals. Results of these inspections are summarized in Table 4. No inspection results have been reported by Korean Airlines to date. The composite rudders have been judged acceptable for continued service as a result of these inspections.

Douglas personnel have non-destructively inspected composite rudders on seven occasions during the third year of flight-service. The inspections were conducted using a portable digital-readout ultrasonic thickness gage (NDI Instruments, Nova 200B or 201A). The instruments were calibrated using a graphite-epoxy reference standard in accordance with the DC-10 Non-Destructive Test Manual. No significant defects were detected during these inspections.

Non-destructive inspections were also conducted by ANZ personnel on aircraft fuselage numbers 69 and 116 during the reporting period. The ANZ inspectors had previously reported three localized bondline anomalies at the rib to skin panel interfaces of the former aircraft (see Reference 1). These anomalies were later confirmed by Douglas engineers. One similar anomaly was also detected on the latter aircraft.

The bondline anomalies were first believed to be local thickness variations at the rib flange to skin panel interfaces. The anomalies are presently believed to be interlaminar resin cracks or disbonds which originated in the fillet regions at the centers of the rib flange to skin panel interfaces, probably during cooldown after the manufacturing cure cycle. The suspected disbonds were not detected during the original non-destructive inspections of the rudders and were first detected in May 1977 after 2948 hours of flight-service on fuselage number 69.

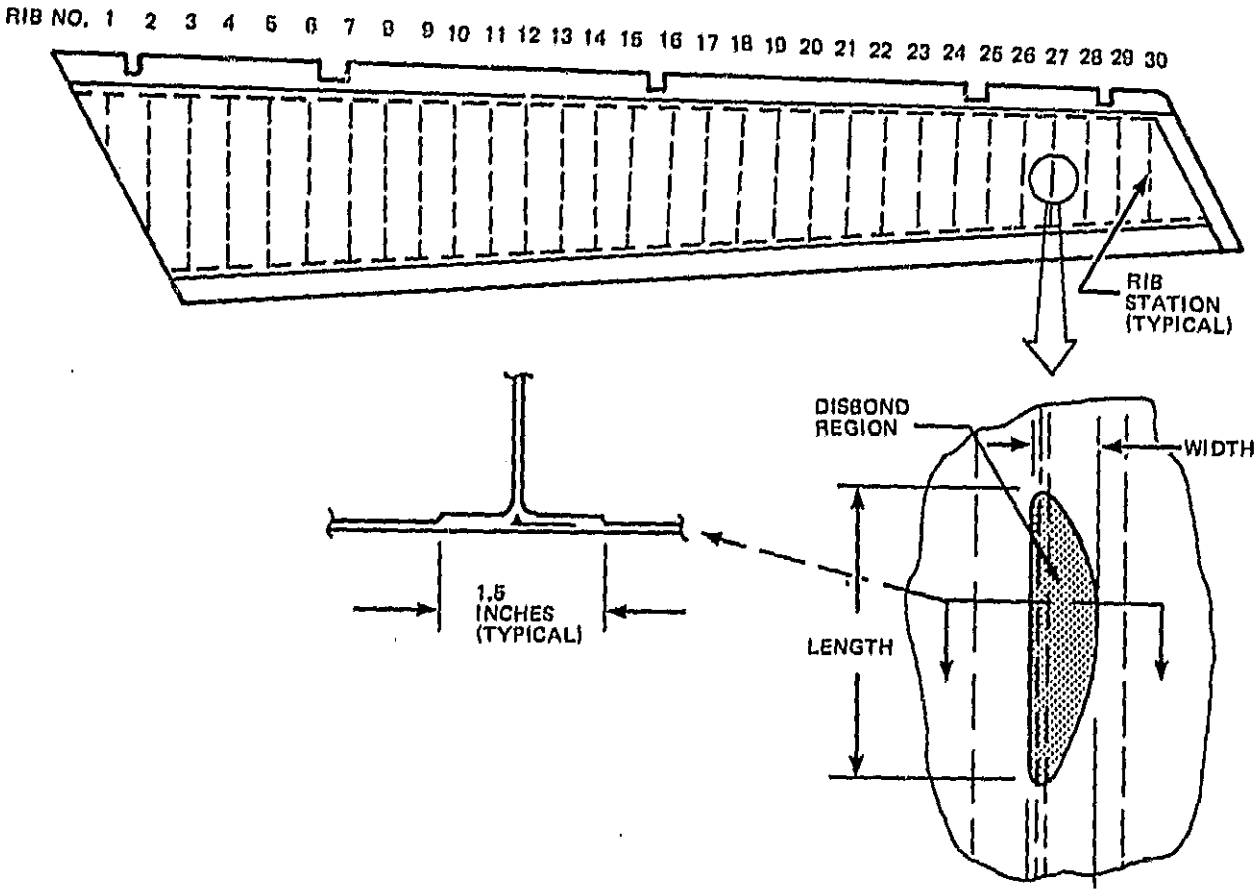
TABLE 4
SUMMARY OF IN-SERVICE INSPECTION RESULTS.

OPERATOR AND FUSELAGE NO.	TYPE OF INSPECTION	INSPECTION PERSONNEL	DATE OF INSPECTION	FLIGHT HOURS ON RUDDER	REMARKS
KOREAN NO. 125	VISUAL	DOUGLAS	12-21-76	1,500	NO DEFECTS
WESTERN NO. 222	ULTRASONIC	DOUGLAS	3-2-77	3,000	NO DEFECTS
			10-2-77	5,499	
			5-2-78	8,028	
			12-8-78	10,617	
			7-28-79	12,930	
TRANS-INTERNATIONAL NO. 110	ULTRASONIC	DOUGLAS	3-18-77	200	NO DEFECTS
			2-22-78	2,758	
			1-29-79	6,224	
AIR NEW ZEALAND NO. 69	ULTRASONIC	ANZ	5-3-77	2,948	3 LOCALIZED BOND DEFECTS
			5-31-77	3,252	RECHECK OF 5-3-77 RESULTS
		DOUGLAS	6-28-77	3,600	RECHECK OF 5-3-77 RESULTS
		ANZ	5-25-78	7,519	NO CHANGE
			11-7-78	9,465	DISBOND GROWTH INDICATED ONE PLACE. SEE TEXT
			1-9-79	10,200	
TRANS-INTERNATIONAL NO. 103	ULTRASONIC	DOUGLAS	1-11-78	3,016	NO DEFECTS
			12-18-78	6,608	
TRANS-INTERNATIONAL NO. 98	ULTRASONIC	DOUGLAS	1-31-78	2,610	NO DEFECTS
			1-16-79	5,840	
	VISUAL		5-6-79	6,745	PAINT CHIP ON F/G LEAD. EDGE. SEE TEXT
AIR NEW ZEALAND NO. 116	ULTRASONIC	ANZ	3-17-78	2,800	NO DEFECTS
	VISUAL		5-25-78	3,563	
	ULTRASONIC		11-1-78	5,512	SMALL BOND DEFECT. SEE TEXT
SWISSAIR NO. 241	ULTRASONIC	SWISSAIR	7-30-79	7,553	NO DEFECTS

Three of four suspected cracked regions are stable with no growth reported during subsequent inspections. One region has indicated some propagation of cracking as shown in Figure 1. The disbonds do not impair the strength or function of the rudders so flight-service is continuing. These regions will be observed for further indications of damage propagation as the flight-service progresses.

A small bonded fiberglass patch was observed on the composite rudder of aircraft fuselage number 96 during the 31 January 1978 inspection. The patch measured approximately 1.5 x 2.5 inches and was located about 18 inches up from the lower edge of the rudder just forward of the rear spar plane. There was no record of the cause of the damage or the date that the patch was applied.

Some paint chipping and cracking was also observed on the composite rudder of aircraft fuselage number 96 during the 6 May 1979 inspection. The paint chipping occurred in the vicinity of the center hinge bracket (near ribs 15 and 16 on Figure 1) on the right-hand side of the fiberglass leading edge segment. The paint on the graphite composite box-section was not affected. The defect was repaired using standard cleaning and painting techniques for fiberglass components.



AIRCRAFT FUSELAGE NO.	DEFECT LOCATION	INSPECTION DATE	FLIGHT HOURS	LENGTH INCHES	WIDTH INCHES	REMARKS
69	RIB 7 RH SIDE UPPER FLANGE	5/3/77 5/25/78 11/7/78 1/9/79	2,948 7,519 9,465 10,200	3.00 3.00 0 0	0.25 0.25 0 0	DISBOND DETECTED NO CHANGE NO DISBOND DETECTED NO DISBOND DETECTED
	RIB 8 LH SIDE UPPER FLANGE	5/3/77 5/25/78 11/7/78 1/9/79	2,948 7,519 9,465 10,200	1.25 1.25 1.25 1.25	0.25 0.25 0.25 0.25	DISBOND DETECTED NO CHANGE NO CHANGE NO CHANGE
	RIB 27 LH SIDE UPPER FLANGE	5/3/77 5/25/78 11/7/78 1/9/79	2,948 7,519 9,465 10,200	1.25 1.25 2.00 2.25	0.25 0.25 0.62 0.62	DISBOND DETECTED NO CHANGE GROWTH INDICATED SMALL GROWTH INDICATED
116	RIB 20 LH SIDE LOWER FLANGE	3/17/78 5/25/78 11/1/78	2,800 3,563 5,512	0 0 0.75	0 0 0.25	NO DEFECTS NO DEFECTS DISBOND DETECTED

FIGURE 1. DEFECT DETECTION ON AIR NEW ZEALAND COMPOSITE RUDDERS

SECTION 3
MOISTURE ABSORPTION INVESTIGATION

A flight evaluation program to determine the moisture absorption of graphite-epoxy laminates in the real-time flight environment was initiated in March 1977. The moisture absorption data are being obtained from flat rectangular specimens of three different graphite/epoxy laminates and two different thicknesses mounted in light weight exposure racks located within an unpressurized fairing area of the DC-10, see Figure 2. The specimens are being exposed to temperature and humidity variations (but not sunlight) for two years of flight service in three separate DC-10 aircraft from Trans-International, Western, and Air New Zealand Airlines. A fourth set of specimens is being exposed to ambient conditions in the Douglas plant in Long Beach, California.

The exposure specimens are 2 inch x 6 inch x 8 plies or 16 plies of unidirectional tape of each of the following three material systems: Thornel 300/Narmco 5208, Thornel 300/Narmco 5209, and Hercules Type AS/3501-6. The filament orientation used in the laminates was [0°/+45°/90°/-45°]ns. Specimens of each material system and laminate thickness are contained in each specimen set.

The four sets of specimens were deployed for exposure as follows:

Set No.	Operator	Aircraft Fuselage No.	Installation Date
1	Douglas	-	8 March 1978
2	TIA	110	13 April 1978
3	Western	252	2 May 1978
4	ANZ	242	20 June 1978

The specimen physical properties and moisture absorption data to date are summarized in Tables 5 through 8. The moisture absorption trends for the various specimen sets are shown graphically in Figures 3 through 10. After about one year of exposure, the average weight gains range from 0.34 to 0.69 percent depending on material system and aircraft installation.

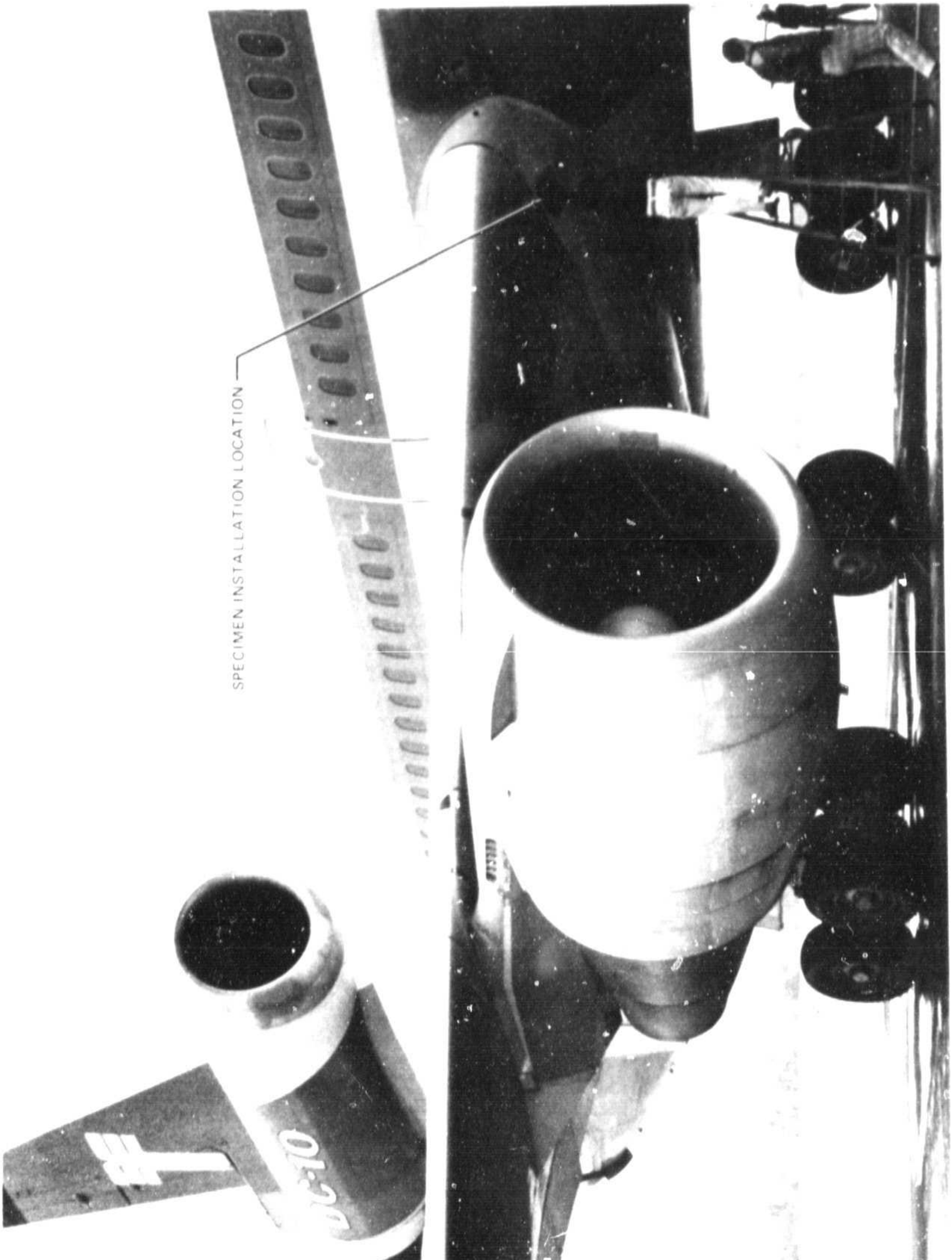


FIGURE 2. LOCATION OF MOISTURE ABSORPTION SPECIMENS IN WING-FILLET FAIRING OF DC-10

TABLE 5
GRAPHITE-EPOXY LAMINATE MOISTURE ABSORPTION DATA
SPECIMEN SET 1— LOCATED AT DOUGLAS LONG BEACH, CA PLANT

SPECIMEN NUMBER	THICKNESS (mm)	THICKNESS (INCHES)	MATERIAL SYSTEM	INITIAL WEIGHT 3/8/78 (GRAMS)	FIRST WEIGHING WEIGHT 4/17/78 (GRAMS)	FIRST WEIGHING WEIGHT INCREASE (PERCENT)	SECOND WEIGHING WEIGHT 6/8/78 (GRAMS)	SECOND WEIGHING WEIGHT INCREASE (PERCENT)	THIRD WEIGHING WEIGHT 8/11/78 (GRAMS)	THIRD WEIGHING WEIGHT INCREASE (PERCENT)	FOURTH WEIGHING WEIGHT 11/8/78 (GRAMS)	FOURTH WEIGHING WEIGHT INCREASE (PERCENT)	FIFTH WEIGHING WEIGHT 3/8/79 (GRAMS)	FIFTH WEIGHING WEIGHT INCREASE (PERCENT)
A-1-1	1.118	0.0440	T300/5208	13.30	13.41	0.83	13.38	0.60	13.40	0.75	13.41	0.83	13.38	0.60
A-1-2	1.105	0.0435		13.27	13.34	0.53	13.32	0.38	13.36	0.68	13.36	0.68	13.33	0.42
A-1-3	1.171	0.0461		13.29	13.28	−0.08	13.37	0.60	13.38	0.68	13.39	0.75	13.37	0.60
A-2-1	2.149	0.0846		26.44	26.57	0.49	26.58	0.53	26.60	0.61	26.62	0.68	26.60	0.61
A-2-2	2.190	0.0862		26.50	*	—	26.64	0.53	26.66	0.60	26.69	0.72	26.65	0.57
A-2-3	2.202	0.0867		26.18	26.23	0.19	26.30	0.46	26.32	0.57	26.34	0.61	26.32	0.53
B-1-1	1.148	0.0452	T300/5209	13.35	13.31	−0.30	13.42	0.60	13.42	0.60	13.44	0.67	13.41	0.45
B-1-2	1.156	0.0455		13.59	13.64	0.37	13.66	0.52	13.68	0.66	13.68	0.66	13.66	0.52
B-1-3	1.158	0.0456		13.49	13.46	−0.22	13.56	0.52	13.57	0.59	13.59	0.74	13.58	0.67
B-2-1	2.309	0.0909		26.98	27.02	0.15	27.09	0.41	27.11	0.48	27.11	0.48	27.11	0.48
B-2-2	2.342	0.0922		27.64	27.73	0.32	27.79	0.54	27.81	0.62	27.79	0.54	27.80	0.58
B-2-3	2.301	0.0906		27.67	27.78	0.40	27.81	0.51	27.83	0.58	27.82	0.54	27.81	0.51
C-1-1	1.090	0.0429	AS/3501-6	13.14	13.17	0.23	13.21	0.53	13.23	0.69	13.18	0.30	13.23	0.68
C-1-2	1.069	0.0421		13.08	*	—	13.15	0.54	13.16	0.61	13.13	0.38	13.19	0.84
C-1-3	1.082	0.0426		13.13	*	—	13.20	0.53	13.21	0.61	13.20	0.53	13.20	0.53
C-2-1	2.151	0.0847		26.41	*	—	26.53	0.49	26.56	0.57	26.56	0.57	26.58	0.64
C-2-2	2.159	0.0850		26.56	*	—	26.70	0.53	26.72	0.60	26.72	0.60	26.72	0.60
C-2-3	2.182	0.0859		26.77	*	—	26.92	0.56	26.93	0.60	26.92	0.56	26.94	0.64

*WEIGHING ERROR

TABLE 6
GRAPHITE-EPOXY LAMINATE MOISTURE ABSORPTION DATA
SPECIMEN SET 2 – TIA INSTALLATION – FUSELAGE NUMBER 110

SPECIMEN NUMBER	THICKNESS (mm)	THICKNESS (INCHES)	MATERIAL SYSTEM	INITIAL WEIGHT 4/13/78 (GRAMS)	FIRST WEIGHING WEIGHT 5/28/78 (GRAMS)	FIRST WEIGHING WEIGHT INCREASE (PERCENT)	SECOND WEIGHING WEIGHT 7/23/78 (GRAMS)	SECOND WEIGHING WEIGHT INCREASE (PERCENT)	THIRD WEIGHING WEIGHT 9/30/78 (GRAMS)	THIRD WEIGHING WEIGHT INCREASE (PERCENT)	FOURTH WEIGHING WEIGHT 12/15/78 (GRAMS)	FOURTH WEIGHING WEIGHT INCREASE (PERCENT)	FIFTH WEIGHING WEIGHT 4/28/79 (GRAMS)	FIFTH WEIGHING WEIGHT INCREASE (PERCENT)
A-1-4	1.158	0.0456	T300/5208	13.66	13.78	0.88	13.73	0.51	13.73	0.51	13.73	0.51	13.73	0.51
A-1-5	1.151	0.0453		13.75	13.80	0.36	13.82	0.51	13.81	0.44	13.84	0.65	13.83	0.58
A-1-6	1.143	0.0450		13.84	*	–	13.92	0.58	13.90	0.43	13.94	0.72	13.92	0.58
A-2-4	2.240	0.0882		27.22	27.39	0.63	27.32	0.37	27.36	0.51	27.41	0.70	27.40	0.66
A-2-5	2.235	0.0880		27.26	27.40	0.66	27.33	0.26	27.38	0.44	27.41	0.55	27.42	0.59
A-2-6	2.240	0.0882		27.16	27.26	0.37	27.23	0.26	27.29	0.48	27.30	0.51	27.31	0.55
B-1-4	1.153	0.0454	T300/5209	13.68	13.79	0.80	13.74	0.44	13.72	0.29	13.76	0.58	13.75	0.58
B-1-5	1.179	0.0464		13.56	13.66	0.74	13.57	0.07	13.60	0.30	13.62	0.44	13.63	0.52
B-1-6	1.163	0.0458		13.78	13.86	0.58	13.81	0.22	13.82	0.29	13.85	0.51	13.86	0.58
B-2-4	2.334	0.0919		27.20	27.33	0.48	27.24	0.15	27.31	0.40	27.34	0.51	27.34	0.51
B-2-5	2.324	0.0915		27.17	27.59	0.39	27.22	0.18	27.27	0.37	27.30	0.48	27.32	0.63
B-2-6	2.299	0.0905		27.46	27.59	0.47	27.53	0.26	27.57	0.40	27.60	0.51	27.63	0.62
C-1-4	1.107	0.0436	AS/3501-6	13.16	13.21	0.38	13.20	0.30	13.22	0.46	13.24	0.61	13.26	0.76
C-1-5	1.062	0.0418		13.24	13.30	0.45	13.27	0.23	13.30	0.45	13.30	0.45	13.29	0.38
C-1-6	1.080	0.0425		13.08	13.14	0.46	13.11	0.23	13.13	0.38	13.15	0.53	13.14	0.46
C-2-4	2.174	0.0856		26.71	26.81	0.37	26.76	0.19	26.84	0.49	26.87	0.60	26.88	0.64
C-2-5	2.210	0.0870		26.91	27.01	0.37	26.97	0.22	27.04	0.48	27.06	0.56	27.07	0.59
C-2-6	2.187	0.0861		26.62	26.72	0.38	26.68	0.23	26.74	0.45	26.77	0.56	26.77	0.56

*WEIGHING ERROR

TABLE 7
GRAPHITE-EPOXY LAMINATE MOISTURE ABSORPTION DATA
SPECIMEN SET 3 – WESTERN INSTALLATION – FUSELAGE NUMBER 252

SPECIMEN NUMBER	THICKNESS (mm)	THICKNESS (INCHES)	MATERIAL SYSTEM	INITIAL WEIGHT 5/2/78 (GRAMS)	FIRST WEIGHING WEIGHT 6/3/78 (GRAMS)	FIRST WEIGHING WEIGHT INCREASE (PERCENT)	SECOND WEIGHING WEIGHT 8/12/78 (GRAMS)	SECOND WEIGHING WEIGHT INCREASE (PERCENT)	THIRD WEIGHING WEIGHT 10/4/78 (GRAMS)	THIRD WEIGHING WEIGHT INCREASE (PERCENT)	FOURTH WEIGHING WEIGHT 1/2/79 (GRAMS)	FOURTH WEIGHING WEIGHT INCREASE (PERCENT)	FIFTH WEIGHING WEIGHT 5/10/79 (GRAMS)	FIFTH WEIGHING WEIGHT INCREASE (PERCENT)
A-1-7	1.029	0.0405	T300/5208	13.74	13.85	0.80	13.87	0.95	13.83	0.66	13.80	0.44	13.81	0.51
A-1-8	1.128	0.0444		13.72	13.85	0.95	13.80	0.58	13.78	0.44	13.78	0.44	13.79	0.51
A-1-9	1.158	0.0456		13.74	13.88	1.02	13.79	0.36	13.81	0.51	13.81	0.51	13.81	0.51
A-2-7	2.261	0.0890		27.26	27.44	0.66	27.41	0.55	27.41	0.55	27.39	0.48	27.40	0.51
A-2-8	2.207	0.0869		27.20	27.37	0.63	27.34	0.52	27.34	0.52	27.32	0.44	27.33	0.48
A-2-9	2.230	0.0878		27.31	27.43	0.44	27.46	0.55	27.45	0.51	27.48	0.62	27.44	0.48
B-1-7	1.118	0.0440	T300/5209	13.53	13.58	0.37	13.58	0.37	13.57	0.30	13.61	0.59	13.57	0.30
B-1-8	1.166	0.0459		13.43	13.56	0.97	13.51	0.60	13.50	0.52	13.52	0.67	13.50	0.52
B-1-9	1.153	0.0454		13.84	13.97	0.94	13.90	0.43	13.93	0.65	13.90	0.43	13.90	0.43
B-2-7	2.311	0.0910		27.50	27.61	0.40	27.65	0.55	27.66	0.58	27.63	0.47	27.61	0.40
B-2-8	2.299	0.0905		27.46	27.57	0.40	27.60	0.51	27.65	0.69	27.59	0.47	27.59	0.47
B-2-9	2.365	0.0931		27.66	27.76	0.36	27.79	0.47	27.82	0.58	27.79	0.47	27.80	0.51
C-1-7	1.118	0.0440	AS/3501-6	13.30	13.33	0.23	13.35	0.38	13.41	0.83	13.37	0.53	13.37	0.53
C-1-8	1.118	0.0440		13.26	13.30	0.30	13.32	0.45	13.33	0.53	13.32	0.45	13.34	0.60
C-1-9	1.077	0.0424		13.18	13.22	0.30	13.23	0.38	13.27	0.68	13.25	0.53	13.27	0.68
C-2-7	2.202	0.0867		26.80	26.91	0.41	26.91	0.41	26.98	0.67	26.94	0.52	27.00	0.75
C-2-8	2.202	0.0867		26.82	26.92	0.37	26.93	0.41	26.99	0.63	26.98	0.60	27.00	0.67
C-2-9	2.159	0.0850		26.73	26.90	0.64	26.83	0.37	26.89	0.60	26.88	0.56	26.90	0.64

TABLE 8
GRAPHITE-EPOXY LAMINATE MOISTURE ABSORPTION DATA
SPECIMEN SET 4 — AIR NEW ZEALAND INSTALLATION — FUSELAGE NUMBER 242

SPECIMEN NUMBER	THICKNESS (mm)	THICKNESS (INCHES)	MATERIAL SYSTEM	INITIAL WEIGHT 6/20/78 (GRAMS)	FIRST WEIGHING WEIGHT 7/24/78 (GRAMS)	FIRST WEIGHING WEIGHT INCREASE (PERCENT)	SECOND WEIGHING WEIGHT 9/27/78 (GRAMS)	SECOND WEIGHING WEIGHT INCREASE (PERCENT)	THIRD WEIGHING WEIGHT 11/17/78 (GRAMS)	THIRD WEIGHING WEIGHT INCREASE (PERCENT)	FOURTH WEIGHING WEIGHT 2/23/79 (GRAMS)	FOURTH WEIGHING WEIGHT INCREASE (PERCENT)
A-1-10	1.181	0.0465	T300/5208	13.83	13.92	0.65	13.92	0.65	13.91	0.58	13.90	0.51
A-1-11	1.158	0.0456		13.84	13.93	0.65	13.93	0.65	13.95	0.79	13.89	0.36
A-1-12	1.158	0.0456		13.79	13.87	0.58	13.87	0.58	13.90	0.80	13.85	0.44
A-2-10	2.240	0.0882		27.45	27.60	0.55	27.61	0.58	27.58	0.47	27.60	0.55
A-2-11	2.283	0.0899		27.41	27.57	0.58	27.57	0.58	27.59	0.66	27.54	0.47
A-2-12	2.243	0.0883		27.31	27.47	0.59	27.47	0.59	27.49	0.66	27.47	0.59
B-1-10	1.148	0.0452	T300/5209	13.59	13.67	0.66	13.66	0.59	13.63	0.37	13.63	0.37
B-1-11	1.156	0.0455		13.55	13.65	0.74	13.62	0.52	13.61	0.44	13.61	0.44
B-1-12	1.168	0.0460		13.78	13.85	0.51	13.86	0.58	13.84	0.44	13.81	0.22
B-2-10	2.311	0.0910		27.63	27.77	0.51	27.75	0.43	27.75	0.43	27.77	0.51
B-2-11	2.311	0.0910		27.62	27.75	0.47	27.73	0.40	27.74	0.43	27.75	0.47
B-2-12	2.271	0.0894		27.36	27.48	0.44	27.49	0.48	27.47	0.40	27.47	0.40
C-1-10	1.102	0.0434	AS/3501-6	13.28	13.35	0.53	13.36	0.60	13.34	0.45	13.33	0.38
C-1-11	1.087	0.0428		13.36	13.44	0.60	13.43	0.52	13.43	0.52	13.42	0.45
C-1-12	1.110	0.0437		13.31	13.37	0.45	13.34	0.23	13.38	0.53	13.37	0.45
C-2-10	2.268	0.0893		26.79	26.91	0.45	26.90	0.41	26.92	0.48	26.92	0.49
C-2-11	2.210	0.0870		27.13	27.27	0.52	27.26	0.48	27.26	0.48	27.28	0.55
C-2-12	2.258	0.0889		27.19	27.35	0.59	27.33	0.52	27.36	0.62	27.34	0.55

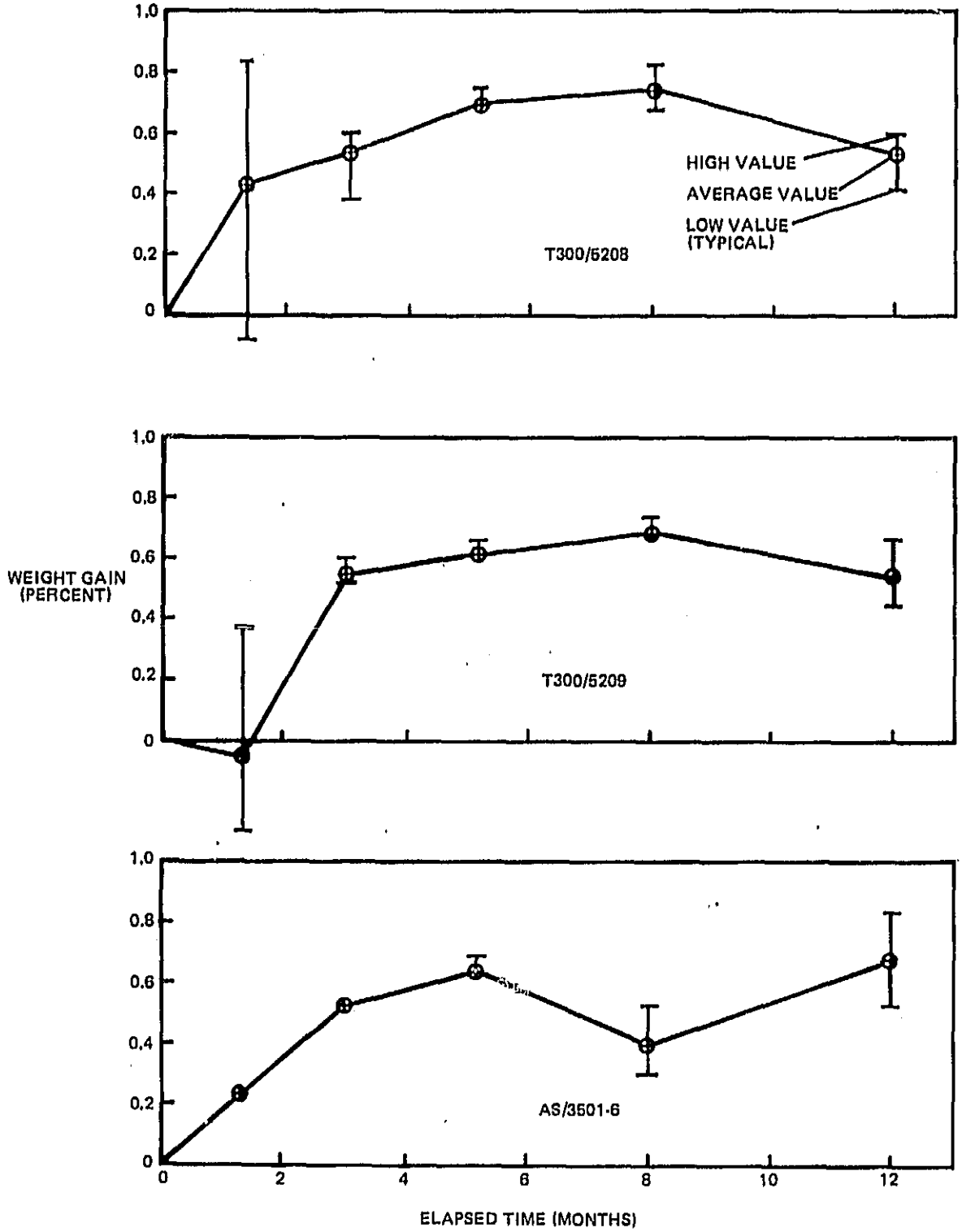


FIGURE 3. MOISTURE ABSORPTION DATA – EIGHT-PLY LAMINATES – SPECIMEN SET 1

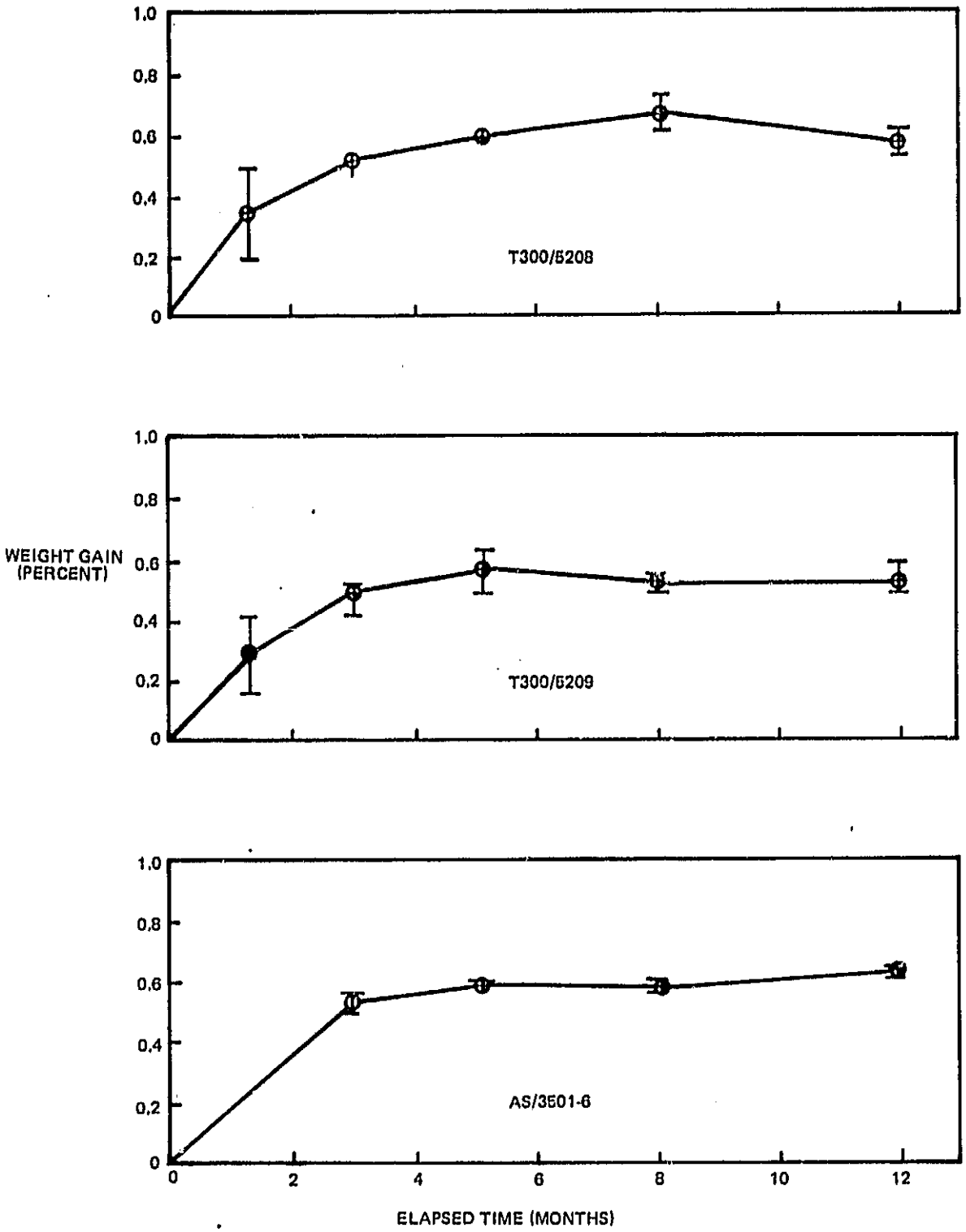


FIGURE 4. MOISTURE ABSORPTION DATA -- SIXTEEN-PLY LAMINATES -- SPECIMEN SET 1

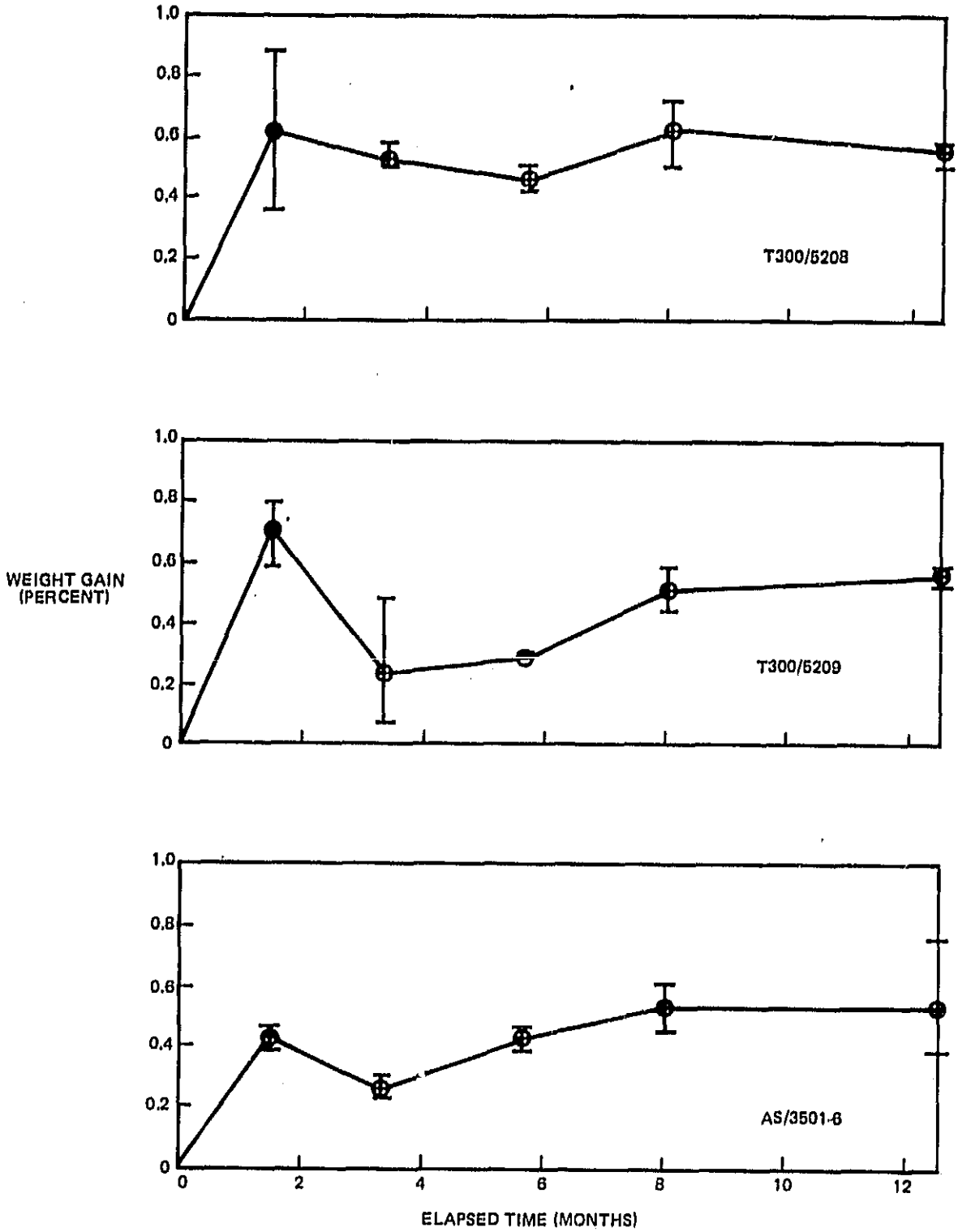


FIGURE 8. MOISTURE ABSORPTION DATA – EIGHT-PLY LAMINATES – SPECIMEN SET 2

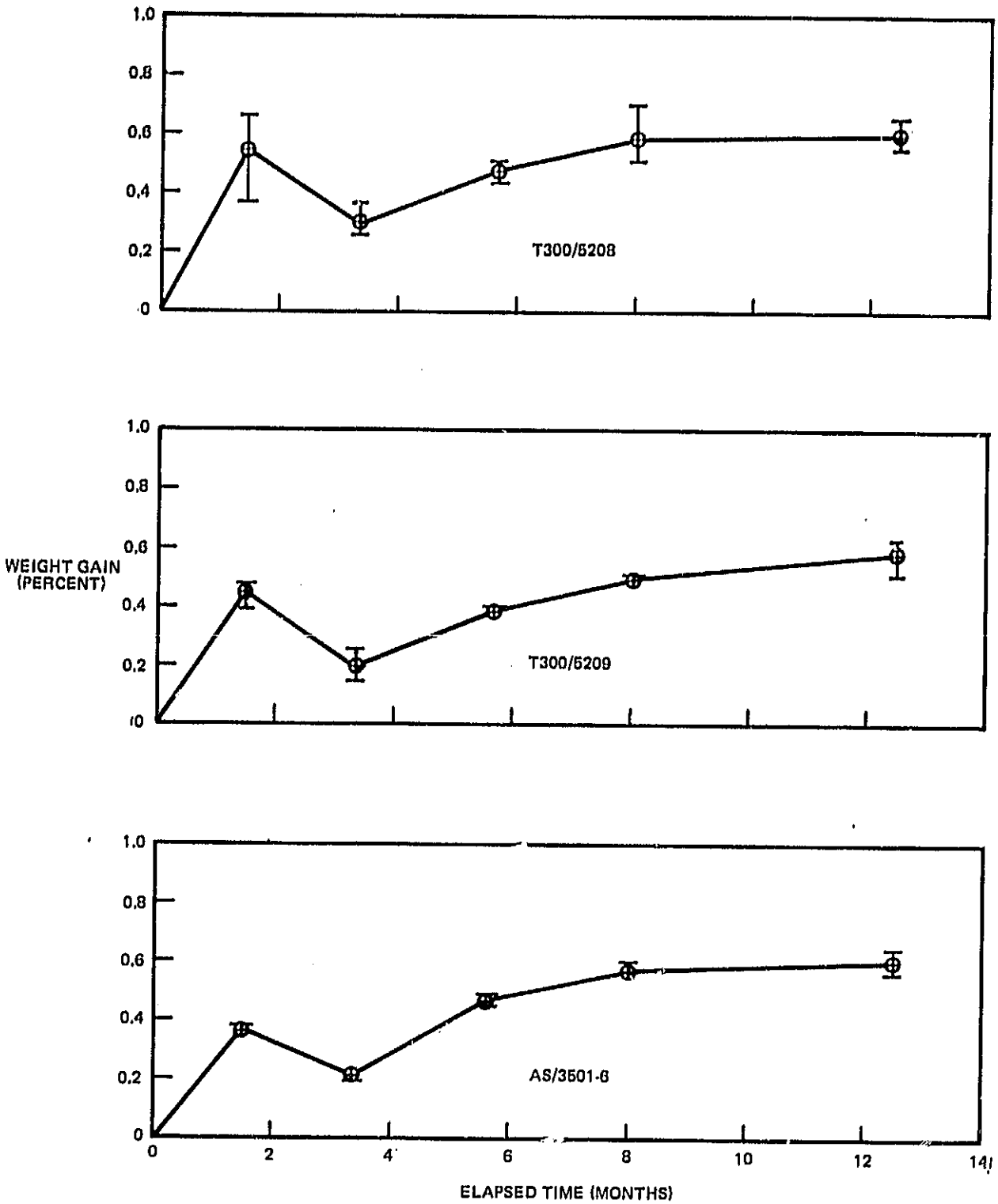


FIGURE 6. MOISTURE ABSORPTION DATA – SIXTEEN-PLY LAMINATES – SPECIMEN SET 2

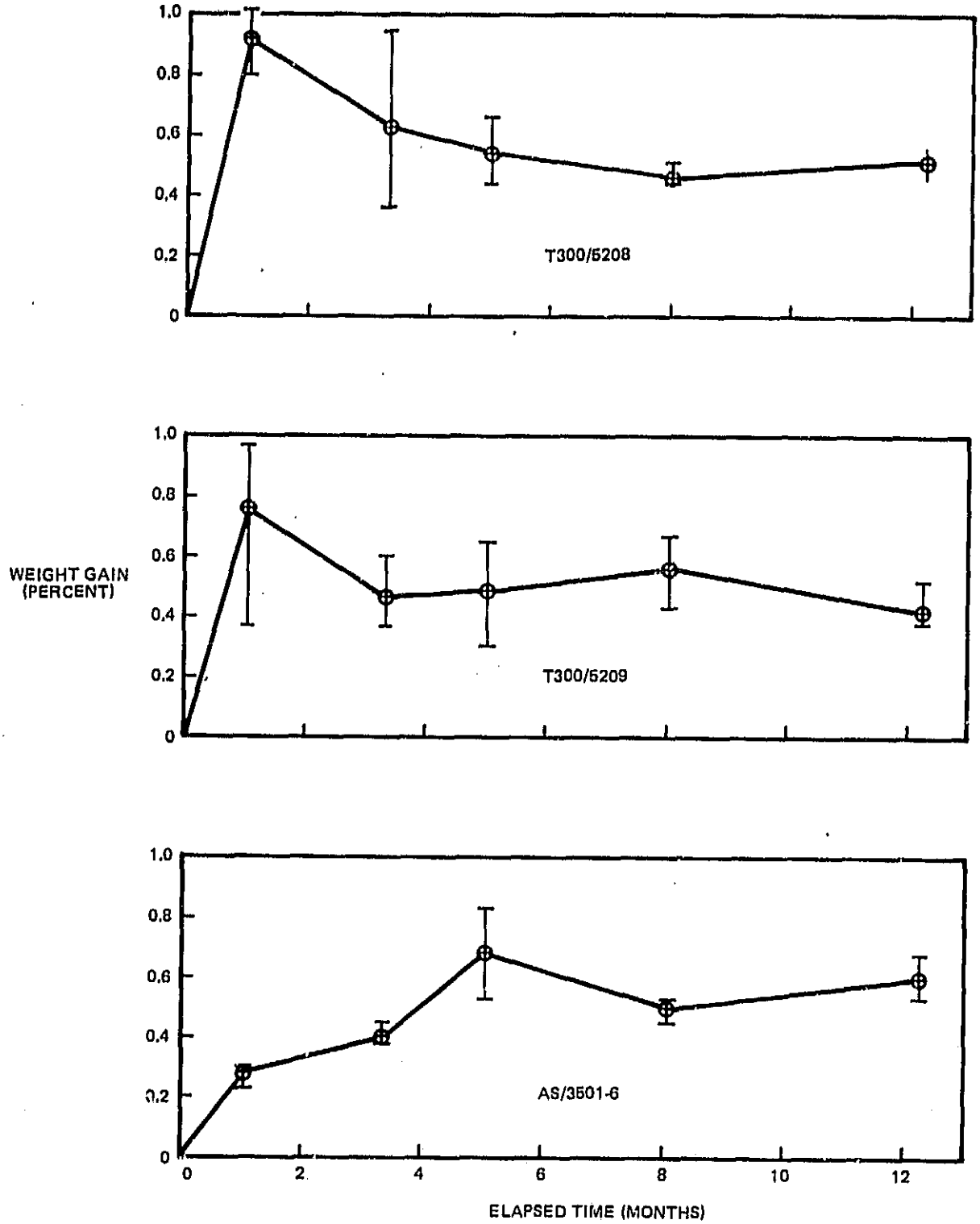


FIGURE 7. MOISTURE ABSORPTION DATA – EIGHT-PLY LAMINATES – SPECIMEN SET 3

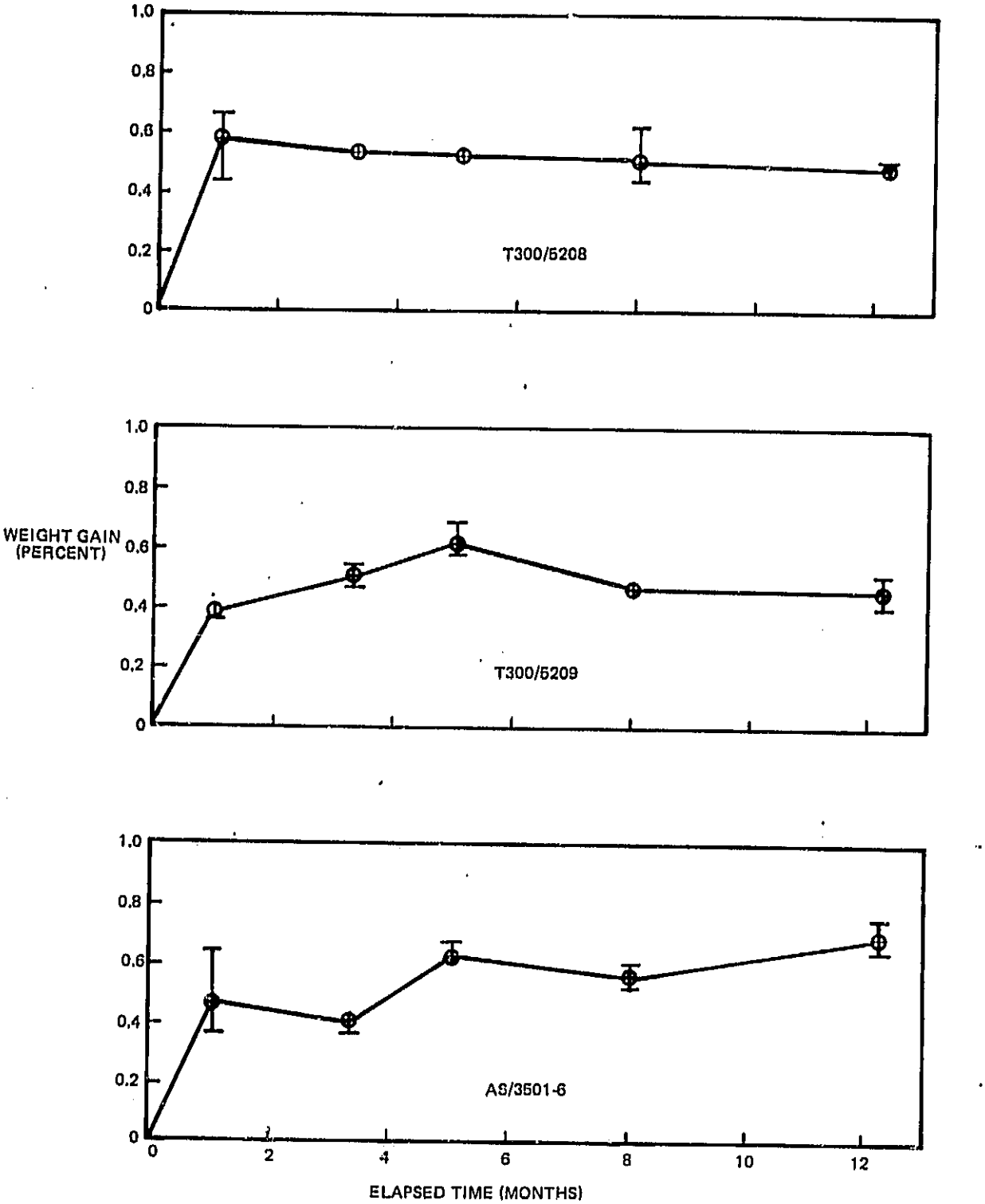


FIGURE 8. MOISTURE ABSORPTION DATA – SIXTEEN-PLY LAMINATES – SPECIMEN SET 3

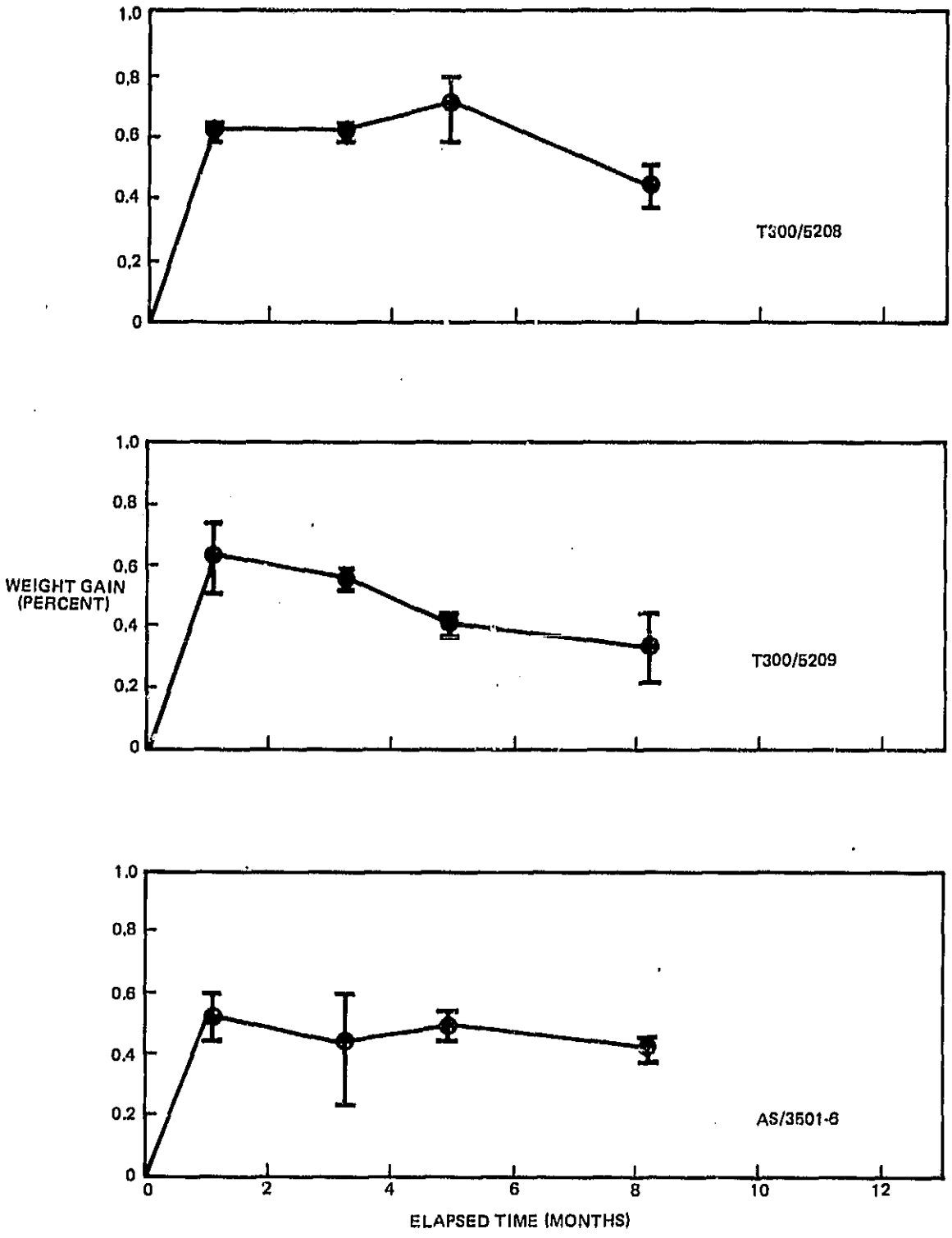


FIGURE 9. MOISTURE ABSORPTION DATA – EIGHT-PLY LAMINATES – SPECIMEN SET 4

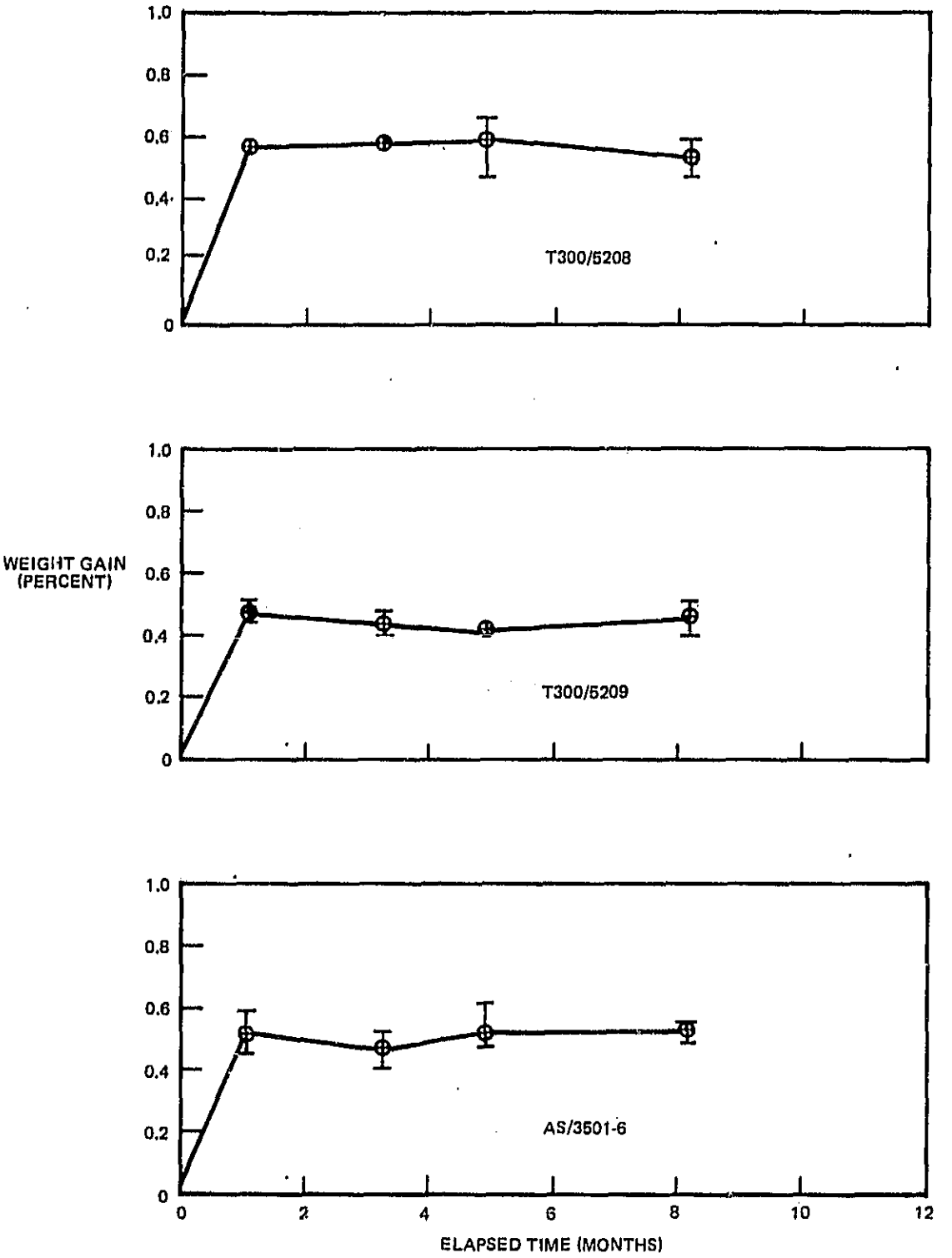


FIGURE 10. MOISTURE ABSORPTION DATA – SIXTEEN-PLY LAMINATES – SPECIMEN SET 4

SECTION 4
REFERENCES

1. "Flight-Service Program for Advanced Composite Rudders on Transport Aircraft," Second Annual Summary Report for Contract NAS1-12954, July 1978.